DATA VISUALIZATION: PLASTIC WASTE CONTRIBUTIONS

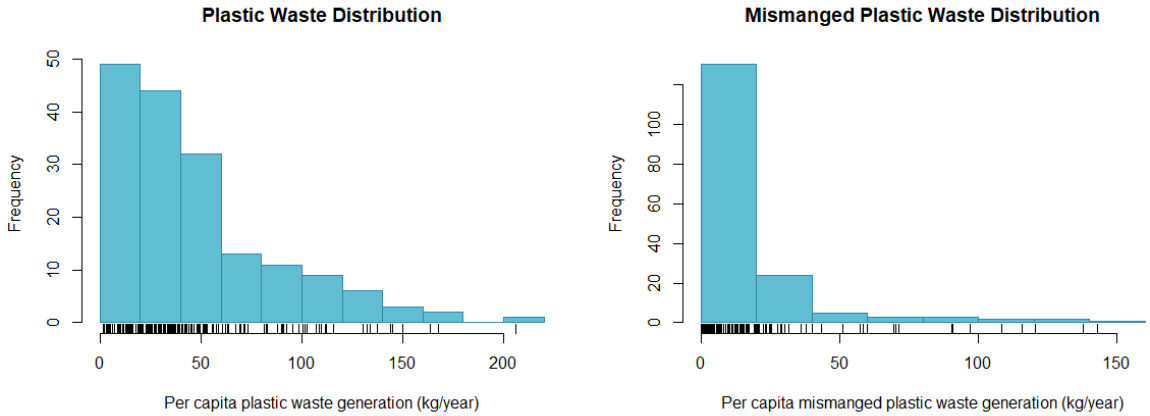
SUMMARY

This assignment analyses data from 2016 on two types of plastic waste – plastic waste generated by countries and plastic waste mismanaged or insufficiently disposed of by countries. The aim is to find solutions which reduce mismanaged plastic waste. Mismanaged plastic waste is especially pollutant as it contaminates oceans and environments.[1] Data shows, plastic waste is the strongest predictor for mismanaged waste. Moreover, mismanaged plastic is dependent on plastic waste. Importantly, high, and upper middle-income countries contribute the most plastic waste per capita, making them also responsible for the highest contribution of mismanaged plastic waste. Therefore, reducing mismanaged plastic waste should involve changing consumerist behavior and reducing the initial demand for plastic in high income countries. Solutions which combat mismanaged plastic waste in lower middle, and low-income countries should focus on infrastructural changes, such as developing effective plastic waste management systems. This is because data proves there is little statistical difference between plastic waste and mismanaged plastic waste in these groups – meaning most plastic waste generated by these groups is mismanaged.

1 DISTRIBUTIONS OF PLASTIC WASTE TYPES PER CAPITA

The distribution of both types of plastic waste per capita can be observed in the histograms Fig. 1. The contribution of waste in kilograms per year kg/year per capita in 2016 can be observed on the x-axis, while the frequency or count within each bar is shown on the y-axis. Individual data points can be seen underneath each histogram inside the rug. Right skews are observable on both histograms as most countries contributed less 50 kg/year of plastic waste and less than 25 kg/year of mismanaged plastic waste. Comparing both histograms, reveals frequency incrementally decreases for plastic waste, and sharply decreases for mismanaged plastic waste. Therefore, while many countries generate large amounts of plastic waste per capita, most of this waste is managed properly. The frequency rug shows few countries contribute less than 0 kg/year of both types of waste. Sharp reduction begins at around 50 kg/year for plastic waste and ≈ 25 kg/year for mismanaged plastic waste. This leaves a few outliers at the left extremities of each histogram.

Figure 1. Histograms and frequency rugs showing the distribution of both types of plastic waste



The ‘plastic waste distribution’ histogram shows very spaced apart data points after 150 kg/year which will be classified and further analyzed. Looking at the rug and table 1, the most extreme outlier is Bermuda which generated 205 kg/year per capita of plastic waste. Bermuda therefore contributes ≈ 5.8

[1] ‘Plastic Pollution’, OurWorldInData, Website.

times more waste than the median waste contribution at 35.61, and ≈138 times more waste the minimum contribution at 1.49.

Table 1 shows the top four contributors to plastic waste manage most of their waste. However, it is notable that the Faeroe Islands only manages 65% of plastic waste, which is significantly less than other high contributors to plastic waste. For instance, Bermuda manages 98% of plastic waste.

In contrast, the outliers for mismanaged plastic waste mismanage all or most of their plastic waste. For example, Mongolia mismanaged 100% of plastic waste, while Aruba mismanaged 90.1% of plastic waste. This indicates these countries do not have sufficient waste management systems. Moldovia contributed more mismanaged plastic waste than plastic waste, which does not match the distribution trend. This may be due importing waste plastic.[2]

Table 1. Outliers in the distribution of plastic waste types

Outlier Waste Type	Country	Plastic Waste. Per-capita(kg/year)	Mismanaged Plastic Waste. Per-capita(kg/year)
Plastic Waste	Bermuda	205.93	4.12
Plastic Waste	Faeroe Islands	167.53	58.64
Plastic Waste	Hong Kong SAR, China	163.45	3.27
Plastic Waste	St Kitts and Nevis	150.01	3.00
Mismanaged Plastic Waste	Moldova	130.15	143.00
Mismanaged Plastic Waste	Mongolia	137.58	137.58
Mismanaged Plastic Waste	Aruba	132.53	120.60
Mismanaged Plastic Waste	Kuwait	115.77	115.77
Mismanaged Plastic Waste	Cayman Islands	133.86	108.43

2 DISTRIBUTIONS OF PLASTIC WASTE TYPES BY QUALITATIVE FEATURES

2.1 PLASTIC WASTE TYPES ACROSS REGIONS

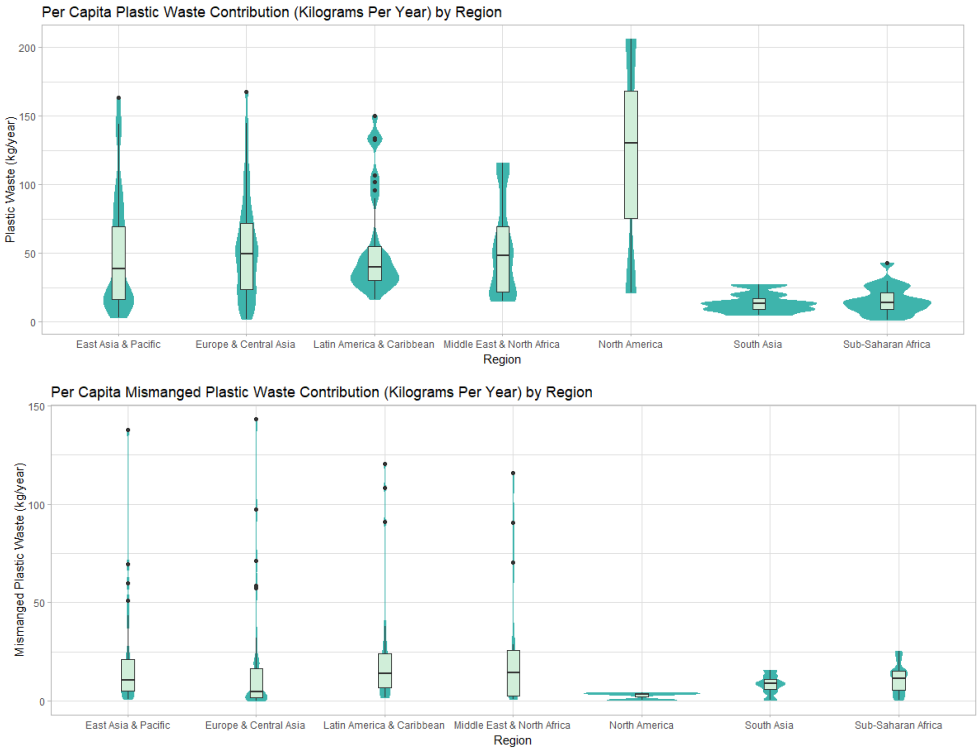
The violin plot Fig.2 shows box plots and density estimations for each region's plastic waste contribution in kg/year. The box plots capture the median, quartiles, maximum, and minimum of the plastic waste contribution by region. The whiskers (vertical lines) capture roughly 99% of the data, and observations outside this range are plotted as points representing outliers. Heavily smoothed density estimates are shown around the box plot. These density estimates provide the information a histogram conveys – a probability density estimate of data points at a given waste contribution.

The violin plots in Fig.2 show: Latin America and the Caribbean, Middle East and North Africa, and North America, do not have any especially low data points for plastic waste. This indicates these regions invest less in reducing the demand for plastic, than other regions. By contrast the regions East Asia and the Pacific and Europe and Central Asia contribute both high and low amounts of plastic waste, indicating some countries in these regions have reduced their demand for plastic.

North America constitutes of only three countries (Canada, Bermuda, and the US), yet each of them contributes a high amount of plastic waste with a median of 130.09 kg/year per capita. This contribution can also be observed in Fig. 3 – those three countries contribute 4.4% of all plastic waste. Although North America produces significant amounts of plastic waste, the amount of mismanaged plastic waste is relatively low with a median of 3.5 kg/year. This observation differs from a strong trend throughout the data Fig.2&3. Namely, although most regions generate less mismanaged plastic waste than plastic waste, the difference is not drastic. By contrast North America shows a 98% decrease. It is possible this gap between plastic waste vs mismanaged plastic waste is connected to the waste exportation of that region.[3]

[2] Law, *et al.* (2020), 6.
[3] Law, *et al.* (2020), 6.

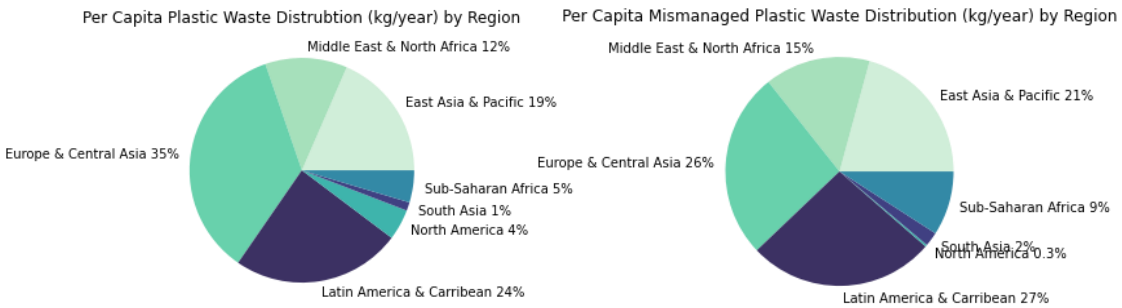
Figure 2. Violin plot exploration of the distributions of plastic waste by region



Overall, Europe and Central Asia contribute the most plastic waste and second most mismanaged plastic waste. The large contribution of mismanaged plastic waste is surprising since the violin plot shows the median value for Europe and Central Asia is low – 4.51 kg/year per capita. However, it must be noted that Europe and Central Asia has multiple outliers and the single highest value for mismanaged plastic waste. Therefore, reducing mismanaged plastic waste in Europe and Central Asia should involve implementing effective waste management systems in outlier countries.

The violin plots and pie charts show South Asia consistently contributes low amounts of plastic waste and mismanaged plastic waste. Most people in South Asia contribute ≈10 times less the amount of waste than people in North America. However, most generate ≈ 2 times more the median amount of mismanaged waste than people in Europe and Central Asia. For this reason, an effective solution may be to develop policies and waste management infrastructure in South Asia which reduce disposal of waste by landfill dumping and marine disposal.[4]

Figure 3. Pie chart exploration of the distributions of plastic waste types by region



[4] Karasik, (2020), 26.

2.2 PLASTIC WASTE TYPES ACROSS INCOME STATUS

High income status counties generate the most plastic waste and the most mismanaged plastic waste Fig.4. The violin plot shows median plastic waste contributions are notably higher than other countries for high income countries. 62.56 kg/year/per capita is the median contribution of plastic waste in high income countries. In context, most people in high-income countries generate ≈ 4 times more plastic waste per capita per year than people in low-income countries.

Interestingly, the pie chart shows high income countries contribute the most mismanaged plastic waste. However, the median value for mismanaged waste in high income countries is the lowest. (Table 2) As the violin plot shows there are many outliers with high values of mismanaged plastic waste, it is most likely these outliers raise the overall value of mismanaged waste – making high income countries the largest contributor to mismanaged plastic waste.

Importantly, for low-income countries the violin plot shows little difference in density estimations and box plots between two types of plastic waste. The median amount of plastic waste generated is 14.2 kg/year per capita, while the median amount of mismanaged plastic waste generated is 13.7 kg/year per capita. Therefore, in 2016 most people in low-income countries mismanaged 97% of their waste. This suggests, low-income countries do not have sufficient waste management systems.

Although lower middle-income countries have the two single highest values, they contribute less mismanaged waste overall than upper middle-income countries Fig.5. Upper middle-income countries are the second largest contributors to plastic waste and mismanaged plastic waste. Nevertheless, lower middle-income countries still contributed ≈ 21% less mismanaged waste and ≈ 63% less plastic waste than high income countries.

Figure 4. Violin plot exploration of the distributions of plastic waste types by income status

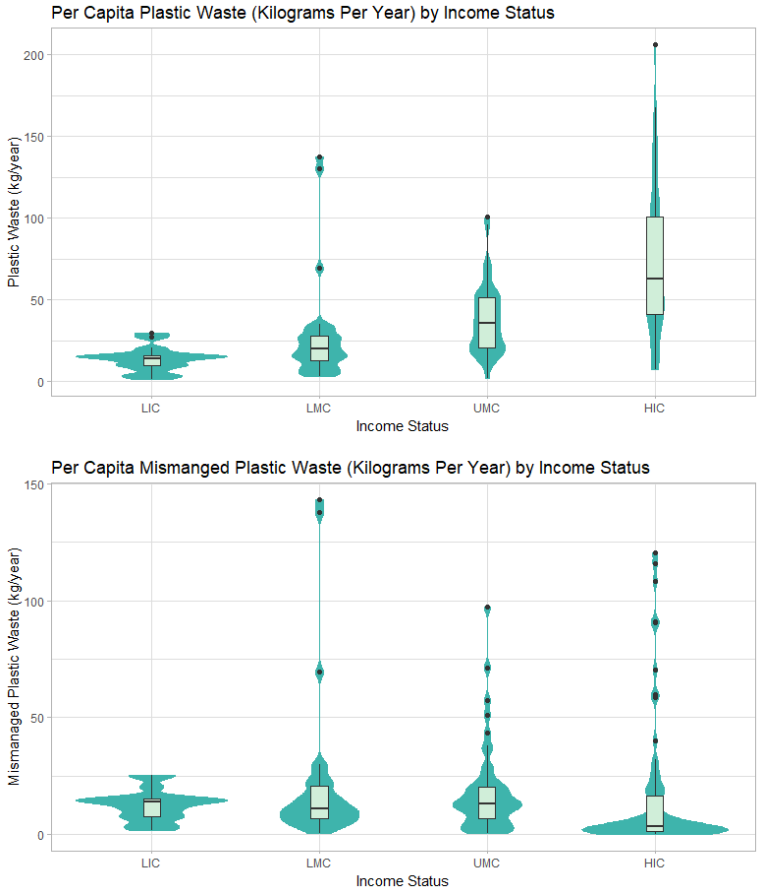
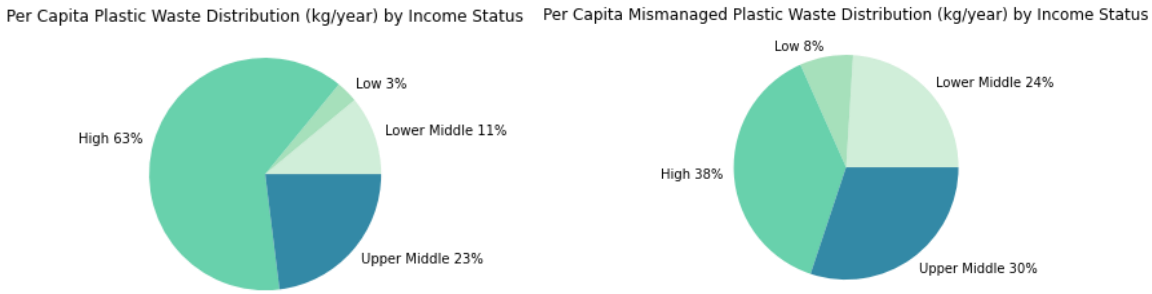


Table 2. Median waste generation values for income statuses

Income Status (descending)	Median Plastic Waste. Per-capita(kg/year)	Median Mismanaged Plastic Waste. Per-capita(kg/year)
High (HIC)	62.56	3.390
Upper Middle (UMC)	35.89	13.21
Lower Middle (LMC)	19.88	11.02
Low (LIC)	14.210	13.785

Figure 5. Pie chart exploration of the distributions of plastic waste types by income status



3 RELATIONSHIPS AND ASSOCIATIONS BETWEEN VARIABLES

In this section the data suggests high income countries, as well as countries with high GDP and high urbanization generate the most plastic waste per capita. Moreover, as mismanaged plastic waste is dependent on plastic waste, these same countries contribute the most mismanaged plastic waste.

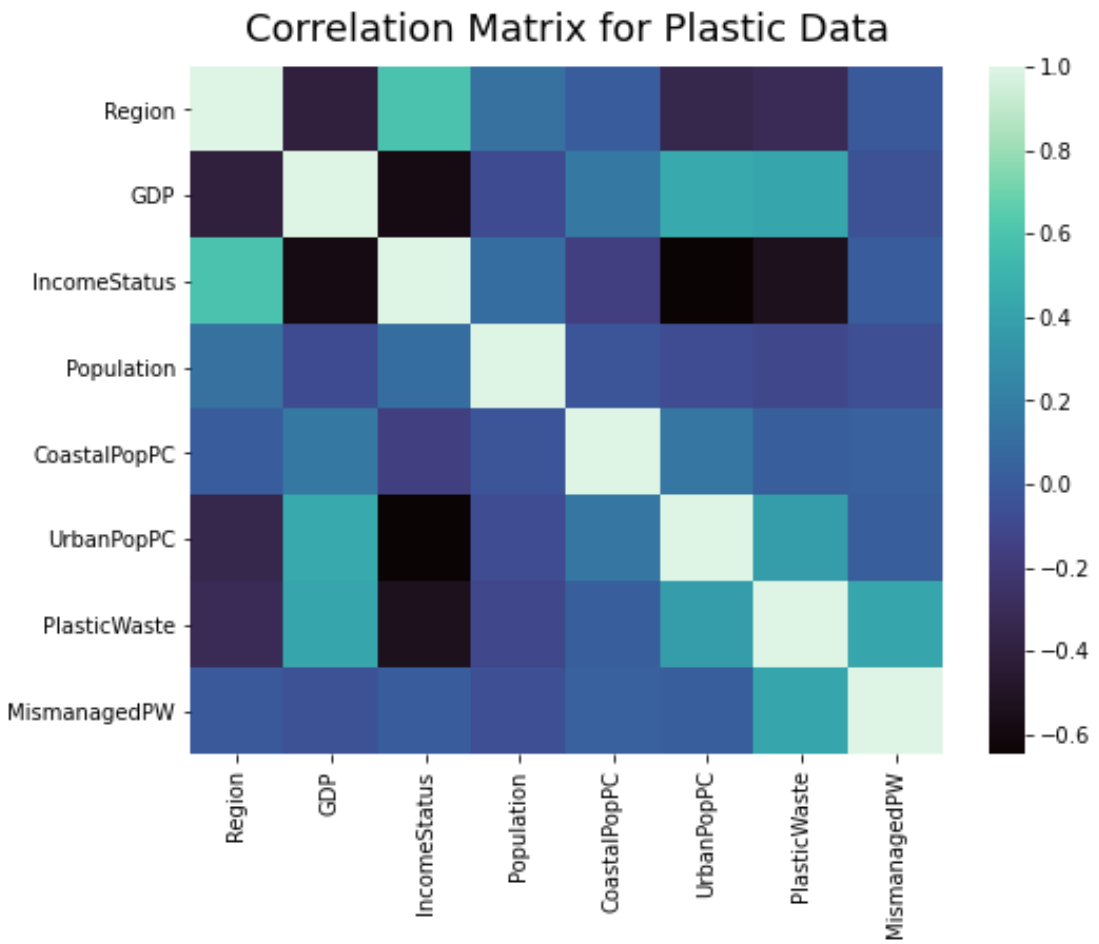
The correlation matrix Fig.6 shows the strength of linear associations between pairs of variables. Values close to 1 or -1 indicate strong linear relationships, while values close to 0 indicate a lack of linear relationship. Analyzing the correlation matrix shows plastic waste is strongly associated with urban population, income status and GDP. The correlation coefficients are ≈ 0.6 and ≈ -0.6. This suggests high income and urbanized countries produce the most plastic waste.

The scatter plot matrix also highlights a relationship between GDP, urban population, mismanaged plastic waste and plastic waste Fig.7. This matrix plots each variable against all others and colors each observation by the qualitive variable income status. Notably, all countries which produce > 150 kg/year per capita of plastic have a high-income status. Most high-income countries have an urban population of ≥ 50 million. Therefore, the most substantial indicators for large plastic waste consumption are high GDP, high urban populations. For this reason, high plastic waste generation may be linked to socio-economic factors such as urbanization and high spending per person.

Backing up this notion, the correlation matrix shows income status is more highly correlated to plastic waste than region. This suggests, the amount of plastic waste contributed is more indicative of lifestyle differences between groups of people rather than geographic differences. This is further suggested by evidence that most countries contributing high amounts of mismanaged plastic waste are highly urbanized. This is because the correlation matrix shows a strong correlation between urban population and mismanaged waste. Moreover, the scatter plot matrix shows most countries contributing > 40kg/year/capita of mismanaged plastic had urban populations > 50 million. Overall, it is unanimous across regions that people living an urbanized lifestyle with a high GDP per capita generally contribute more plastic waste per year.

Importantly, there may be a colinear relationship between mismanaged waste and plastic waste. This is because plastic waste and mismanaged plastic share the strongest correlation coefficient and linear pattern. Fig. 6&7. The scatter plot matrix shows all countries which produce > 60 kg / year per capita of mismanaged plastic waste, also produce ≥ 50 kg/year per capita of plastic waste. For this reason, mismanaged waste is colinear or dependent with plastic waste. The collinearity between mismanaged plastic waste in explains why high-income countries produce so much mismanaged plastic waste collectively, despite producing low median values for mismanaged waste per capita.[5] Consequently, the best solution to reducing mismanaged plastic waste is to produce less plastic that is not practically or economically recyclable, or that easily escapes into the environment.[6]

Figure 6. Correlation matrix for plastic data, highlighting relationships between variables



[5] Referring to figure 2, we can see the median value for mismanaged plastic waste is the lowest in the high-income status group.
[6] Law, *et al.* (2020), 4.

Figure 7. Scatter plot matrix for plastic data, highlighting relationships between GDP, urban population, mismanaged plastic waste and plastic waste.

4 THE IMPACT OF INCOME STATUS AND REGION

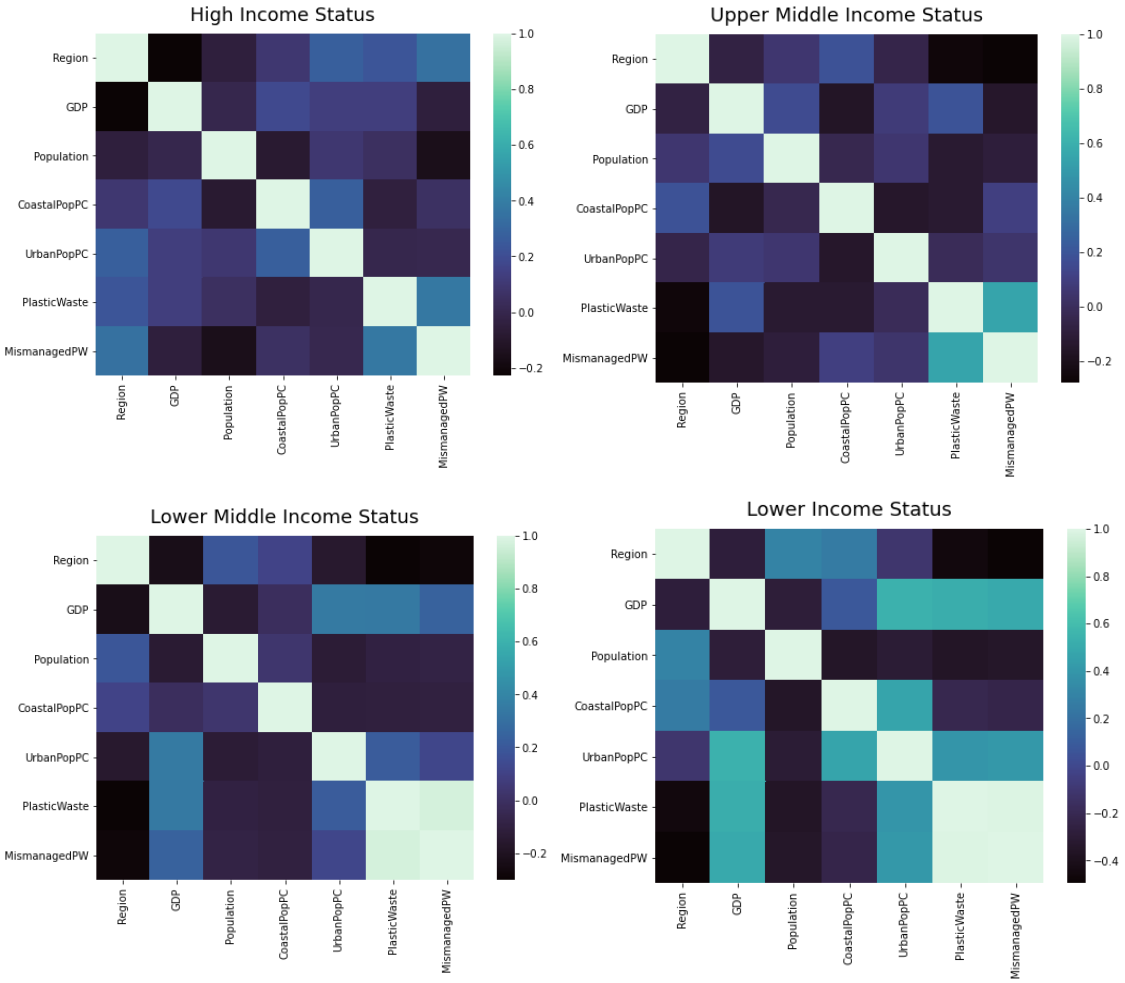
This section analyses how impact status and region affect the relationships between types of plastic waste and other variables. Here several correlation matrices are presented. Each matrix presents changes in variable relationships between income statuses Fig.8. Most strikingly, there is no difference between plastic waste and mismanaged plastic waste in low-income countries and there is very little difference in lower middle-income status countries. This in sharply contrasts high and upper middle income status countries which show less correlation between plastic waste and mismanaged plastic waste. This shows lower-middle and low-income countries mismanage large percentages of their waste. For this reason, lower-middle and low-income countries should look towards building sufficient waste management infrastructure. Additionally, developing policies which manage waste disposal, such as marine litter, may be effective. [7]

Another important observation is that GDP is negatively related to plastic waste and/or mismanaged plastic waste in all groups other than high income status. Therefore, in most income groups lower GDP per capita increases waste generation. In high income countries high GDP per capita increases waste generation. However, it must be noted that the correlation coefficient for GDP in high income countries is low. This reflects the observation that a few countries with an exceptionally high GDP of ≥ 10,0000 per capita contributed low amounts of mismanaged plastic waste Fig.8.

[7] Karasik, (2020), 190.

With correlation coefficients of ≈ 0.4 and ≈ -0.5, region is strongly correlated with mismanaged waste in high and low-income status groups. This indicates that although regions in these income groups share similar financial and developmental qualities, they differ in their waste management systems. Therefore, it is possible differences in plastic management polices across regions affect waste contributions, even in the same income status group. Regional contributions to types of plastic will be further explored in section 5.

Figure 8. Correlation matrices for each income status group, showing relationships between income status, region, and other variables.



5 EXTRA FINDINGS

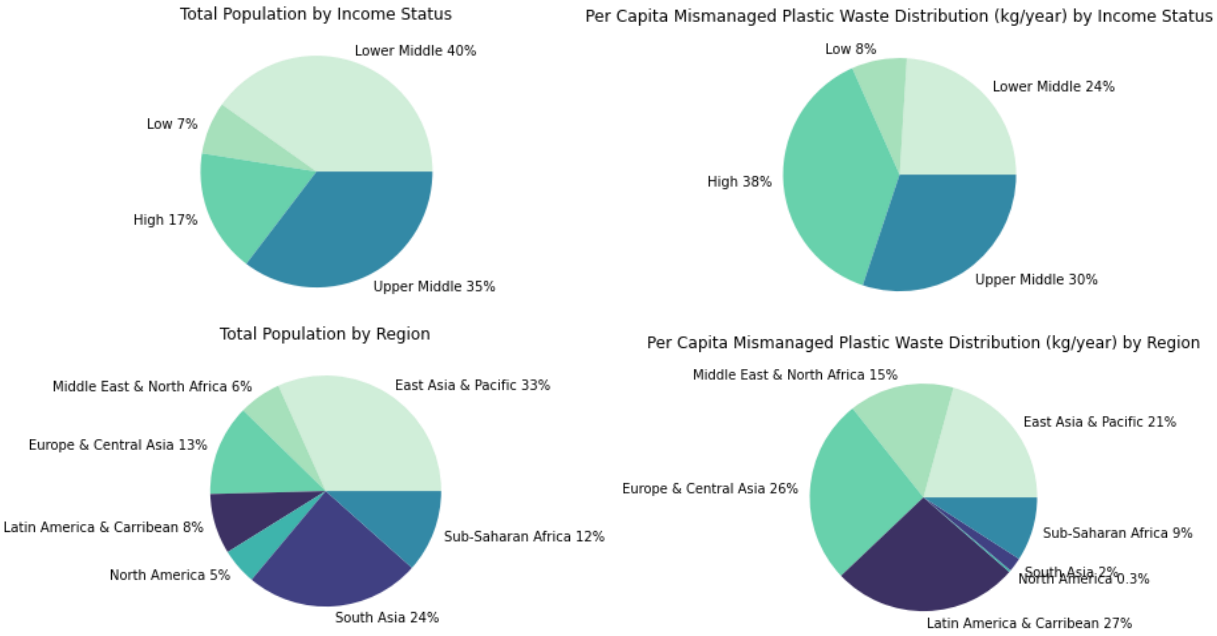
5.1 SHARES OF MISMANAGED WASTE

This section seeks to highlight the imbalance in shares of total mismanaged plastic per capita between the total populations of each income status and region. As mismanaged plastic waste is at high risk of entering the ocean, it is important to find an effective solution to reducing it.[8] Firstly, it is important to understand the global picture of how mismanaged waste is distributed throughout groups. Notably, high income status countries only account for 17% of the world's population Fig.9 and only cover 5 of the 7 regions Fig.10. However, this 17% of people account for 38% of the world's mismanaged plastic waste. Therefore, plastic waste solutions which target the high-income group may subsequently reduce global mismanaged plastic. For example, reducing plastic packaging and improving the recycling capabilities for plastic packaging in

[8] 'Mismanaged Plastic Waste', OurWorldInData, Website.

high income countries is an effective strategy.[9] Similarly, reducing the consumption of plastic carrier bags to 40 lightweight bags per capita yearly by 2025 is an effective solution. [10]

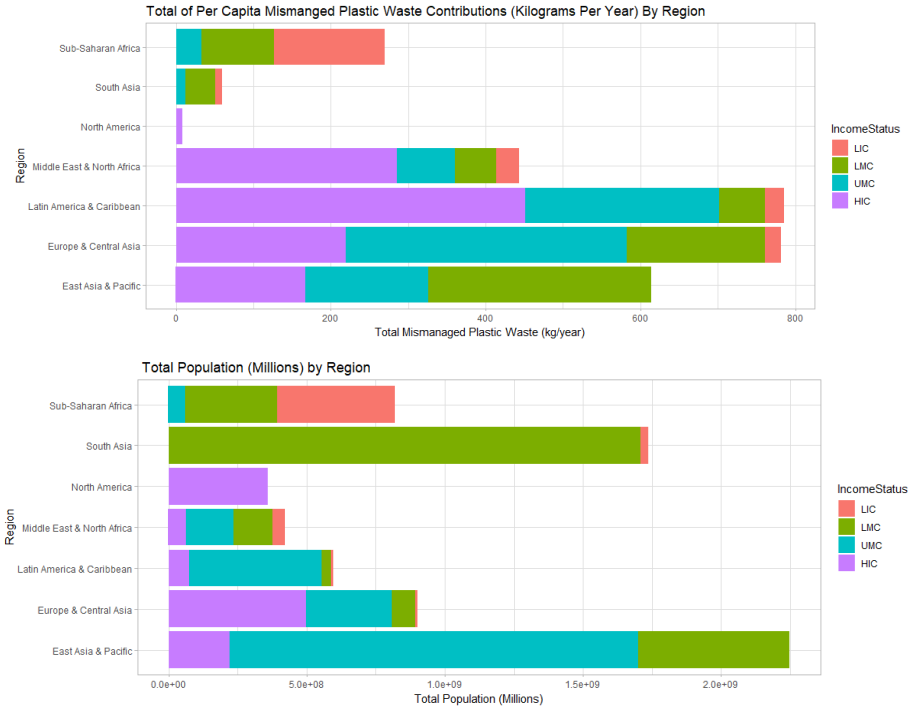
Figure 9. Pie charts showing an imbalance between populations of groups and mismanaged plastic waste.



By region, the pie charts show only two regions (Latin American and the Caribbean, Europe, and Central Asia), account for 21% of the world's population Fig.9. Yet, these regions are responsible for 53% of mismanaged plastic waste. Latin America and the Caribbean makes up only 8% of the global population and contribute 27% of the world's mismanaged plastic waste. This sharply contrasts South Asia which has over 2 times the population of Latin America and the Caribbean generates ≈ 14 times less mismanaged plastic waste. Notably, Latin America and the Caribbean also have proportionately more high-income status countries than other regions, including South Asia which has no high-income countries Fig.10. This is further evidence to suggest high income status increases mismanaged plastic waste. Europe and Central Asia is also not a dominant global population and yet generates 26% of the world's mismanaged plastic waste. If Latin America and the Caribbean and Europe and Central Asia were to reduce their total mismanaged plastic waste capita to 443.25 kg/year (the same amount as the Middle East and North Africa) this would reduce the global mismanaged waste capita contributions by 23%. Consequently, this highlights how mismanaged plastic waste could be significantly reduced by changing the unstainable lifestyles of just a fraction of the world's population.

[9] Karasik, (2020), 174.
[10] Karasik, (2020), 186.

Figure 10. Bar charts showing total mismanaged waste and population by region, showing how high-income status groups and small populations monopolize mismanaged plastic waste generation.



5.2 CONCLUSION (MODELLING STRATEGY AND SOLUTIONS)

Overall, plastic waste, income status, GDP and urban population are most strongly related to mismanaged plastic waste. Therefore, if this analysis was to be used to inform feature selection in modelling, it would be important to include these predictors. It may also be important to include region, as graphs show notable differences in waste contributions between regions. Usefully, this assignment highlights directions which could help reduce mismanaged plastic waste. In low-income countries, sufficient waste management infrastructure needs to be developed. However, more significantly, high income countries need to produce less plastic waste. Although most high-income countries have sufficient waste management systems, and a strong public desire to recycle, the plastic waste they generate leads to high amounts of mismanaged plastic.[11] This is because mismanaged plastic is dependant on plastic waste. Therefore, to drastically reduce plastic globally, solutions should involve decreasing consumerist behaviour and the dependence on plastic in high income countries. This may decrease plastic waste kg/year/ per capita and subsequently decrease mismanaged plastic waste.

Bibliography

Karasik, R., Vegh, T . Diana, Z. Bering, J. Caldas, J. Pickle, A. Rittschof, D and Virdin, J. (2020). '20 Years of Government Responses to the Global Plastic Pollution Problem: The Plastics Policy Inventory'. NI X 20-05. Durham, NC: Duke University.

Law, K. Starr, N. Siegler , T. Jambeck, J. Mallos, N., Leonard, G (2020) 'The United States' contribution of plastic waste to land and ocean', Science Advances, Vol 6, Issue 44, DOI: 10.1126/sciadv.abd0288

Ritchie, H. and Roser, M (2018) 'Plastic Pollutant' < https://ourworldindata.org/plastic-pollution > [Last accessed 19 March 2022]

[11] Law, *et al.* (2020), 3.